A Relativistic Symmetry in Nuclei and Effective Field Theory

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The dynamics of neutrons and protons in nuclei have been successfully treated nonrelativistically. Therefore it came as a surprise that the (almost) equality of certain pairs of energy levels of quantum states (quasi-degeneracy) in heavy nuclei can be explained by a relativistic symmetry [1]. This symmetry is called pseudospin symmetry because it has the same mathematical properties as spin but different physical properties. For example, the quasi-degenerate quantum states have different radial quantum numbers and different orbital angular momenta, features not possible with spin, which made the reason for their quasi-degeneracy difficult to penetrate. Pseudospin entangles both spin and momentum of the nucleons in the nucleus in such a way to make such transitions possible.

Since pseudospin symmetry seems to be more valid than spin in nuclei, the question arises if there is a fundamental rationale for this symmetry. Recently effective field theories have been developed that derive effective nucleon-nucleon interactions. These effective nucleon-nucleon interactions involve the spin. We may ask why don't these expansions naturally involve the pseudospin as well? We have investigated this issue and discovered some interesting answers.

First we found that the spin-spin interaction between nucleons is equivalent to the pseudospin-pseudospin interaction between nucleons. Second, we showed that the tensor interaction is a spin-pseudospin interaction. This is an interesting insight and implies that the tensor interaction violates both spin and pseudospin equally. These results demonstrate that effective field theories put spin and pseudospin on an equal footing but, by the same token, there is no need to introduce pseudospin.

However, the two body spin-orbit and the two body pseudospin-pseudo-orbit interactions are not equivalent and imply different physics. The two body pseudospin-pseudo-orbit interaction can be written in terms of a linear combination of the two body spin-orbit interaction and the tensor interaction. Although the tensor interaction conserves neither spin or pseudospin, the two body spin-orbit interactions conserves spin but not pseudospin and, vice-versa, the two body pseudospin-pseudo-orbit interaction conserves pseudospin but not spin. This suggests that, instead of writing the effective nucleon-nucleon interaction in terms of the tensor interaction, a more revealing exposition would to be to write the effective nucleon-nucleon interaction as a linear combination of the two body spin-orbit interaction and two body pseudospin-pseudo-orbit interaction. If the strength of the two body pseudospin-pseudo-orbit is much larger than the strength of the two body spin-orbit interaction, then the nucleon-nucleon interaction would have an approximate dynamical pseudospin symmetry and would explain the observance of approximate dynamical pseudospin symmetry in nuclei. This program is being carried out.

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[1] Joseph N. Ginocchio, *Physics Reports* **414**, 165 (2005).

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